Development and Experimental Investigation of a Pendulum-Based Wave Energy Converter for Met-Ocean Sensing

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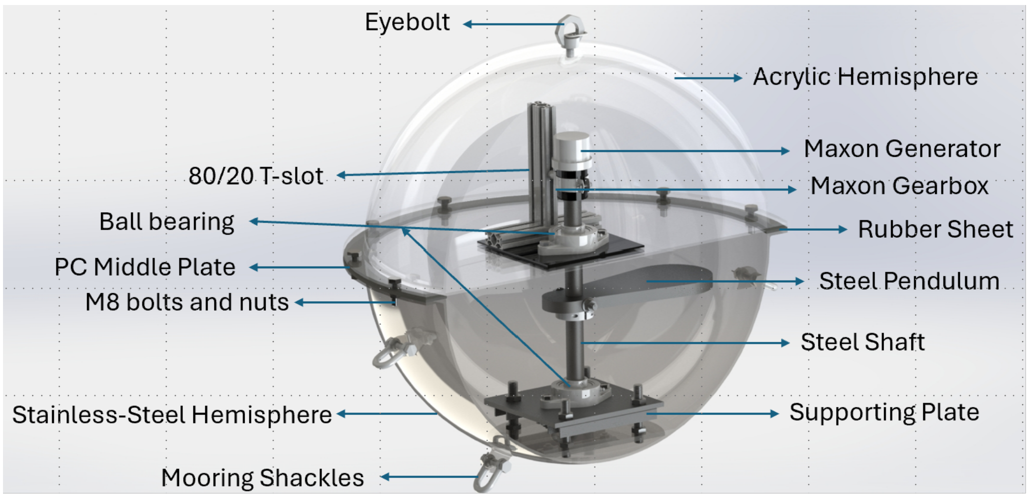
Abstract

Ocean energy presents a vast, underutilized resource for sustainable power generation.Regular and accurate oceanographic data collection is essential for understanding marine environments, supporting climate research, and ensuring sustainable management of ocean resources.Continuous data collection helps in monitoring ocean temperature, salinity, wave dynamics, and water quality, which are vital for assessing climate change impacts, predicting extreme weather events, and guiding maritime operations.Traditional marine sensors depend on battery power or solar energy, both of which face operational challenges such as limited power capacity and environmental constraints. The development of autonomous and energy-efficient ocean monitoring systems is critical to overcoming the limitations of conventional data collection methods, such as ship-based surveys and battery-dependent sensor networks. Wave energy converters (WECs) offer a sustainable alternative by leveraging natural wave motion to provide consistent energy for long-term data collection. We are proposing an innovative, wave-powered autonomous met-ocean sensor suite buoy designed for oceanographic data collection and renewable energy generation.This study focuses on the design, development, and experimental evaluation of the proposed design. The design integrates mechanical, electrical, and environmental engineering disciplines to develop a pendulum-based Wave Energy Converter (P-WEC) that harnesses ocean wave energy to power onboard sensors, enabling real-time data transmission via radio waves or satellite transmission in remote marine environments. The device is a low-cost, sustainable solution that addresses the growing demand for high-resolution oceanographic data while contributing to the blue economy.



Buoy's Pendulum Design Configuration

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The proposed system harnesses the oscillatory motion of ocean waves to drive a pendulum mechanism, converting mechanical energy into electrical power to sustain onboard sensors for long-term environmental monitoring.The design emphasizes environmental sustainability, utilizing corrosion-resistant materials and minimizing ecological impact. The system incorporates a dual power transmission mechanism with fail-safe features, ensuring reliable data collection and transmission even in harsh oceanic conditions. An AC generator with a rectifier circuit was selected for optimal power conversion. Additionally, the study explores the scalability of the technology, with potential applications ranging from small coastal communities to large-scale utility projects. The device's performance was validated and tested in controlled wave tank experiments, with results indicating promising energy conversion efficiency and operational reliability. Testing was conducted on a scaled model of 1:8.5 of the original 6 m diameter buoy to suit the testing conditions and power capabilities. The onboard batteries served as the energy storage system that powered the sensors. Temperature and turbidity sensors were used for sensing, but the scale of sensors for the full-scale model is significantly larger.

The study contributes to advancing ocean-based renewable energy solutions, addressing challenges in offshore energy sustainability while providing critical data for climate research and marine operations. The results demonstrate the potential of the proposed technology for long-term deployment in oceanographic monitoring, offshore infrastructure surveillance, and maritime security applications.